



Title of Investigation:

The Feasibility Study of a Novel Multipurpose Fiber-Injected Microspherical Laser System

Principal Investigator:

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Other In-house Member:

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Initiation Year:

FY 2004

Funding Authorized in FY 2004:

\$0

Funding Authorized in FY 2005:

\$50,000

Actual or Expected Expenditure of FY 2005 Funding:

In-house: \$42,400; and Contracts: \$7,600

Status of Investigation at End of FY 2005:

To be continued in FY 2006, with additional expected FY 2006 funding of \$50,000.

Expected Completion Date of the First Prototype:

September 2006

Purpose of Investigation:

The purpose of our investigation is to build a compact, rugged, and inexpensive laser system made of microspheres. This microspherical laser is a highly versatile laser system that can detect organic compounds on Moon and Mars, for example. It also can be used on Earth to measure wind speeds, chlorophyll concentrations, ocean temperatures, and the extent of the polar ice cap meltdown. The microspheres are made of silica glass, doped with different lasing materials. Once these microspheres get excited, they emit laser lines at specific wavelengths depending on what they are infused with. This laser technology is insensitive to temperature and pressure variations,

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and therefore, immune to the harsh space environments. A couple of designs are in place to improve the technology's efficiency.

Accomplishments to Date:

Although we received funding for Phase I in the middle of the fiscal year (April 8), we succeeded in achieving our objectives for the first year.

1. We hastened the process for ordering the microspheres, the hollow fiber, and other essential components. We hired a Lab View contractor to fix the spectrometer and we completed the setup to do the experiment. Last, we examined different sizes of microspheres (from 5 to 20 microns in diameter).
2. Our preliminary studies demonstrated that silica microspheres doped with rhodamine 6G lase at a low-energy threshold of only $\sim 2.3 \times 10^4 \text{ W/cm}^2$. The fluorescence lines suffer multiple internal reflections within the microsphere, which acts as a mirrorless cavity and a gain medium. Above threshold, the fluorescence lines gain enough energy to become laser lines.
3. A discloser form is signed with the technology transfer office at NASA-GSFC.
4. A paper titled "Multipurpose Microspheres-Fiber Laser" was sent for presentation to the CLEO/QELS Conference at Long Beach, CA.
5. The spectral features of the radiation emitted by the microspheres were recorded using a 1200-groove/mm, 750-mm spectrometer with a computer control driver using Lab View software. The 532-nm doubled beam from a Q-switched Nd:YAG laser operating at 10 Hz excited the particles in a 1-mm optical path length cuvette. The microspheres were provided at a concentration of 1 percent solid in a viscous fluid to slow their sedimentation. Figure 1 represents the green pump signal at 532 nm. The spectrum of the pure laser dye in acetone is peaked at 565 nm as shown in figure 2. The spectrum of the spheres at laser energy blow-lasing threshold is shown in Figure 3.

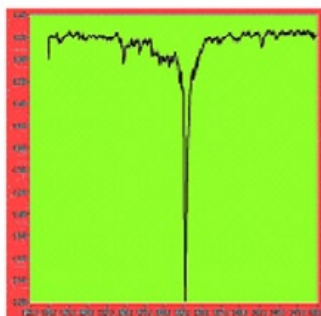


Figure 1. The laser signal

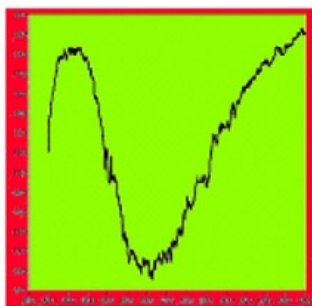


Figure 2. The dye spectrum

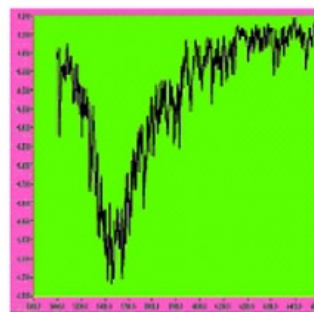


Figure 3. The spheres spectrum

The spectral data of silica microspheres show more prominently equally spaced laser lines, as shown in figures 4 and 5 for 12- and 5-micron size spheres, respectively. The whispering gallery modes are equally spaced with 5-nm spacing. The 12-micron spheres peaked at 565.5 nm, while the 5-micron spheres peaked at 563.5 nm. The threshold for lasing occurred at about $2.3 \times 10^4 \text{ W/cm}^2$. The spectral range did not vary in silica spheres of 5 and 12 microns sizes.

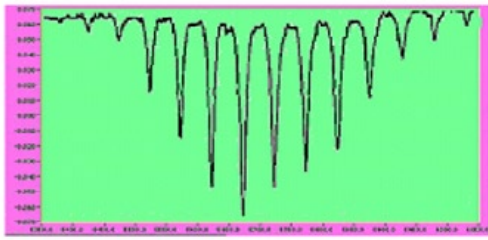


Figure 4. The 5-micron silica spectrum

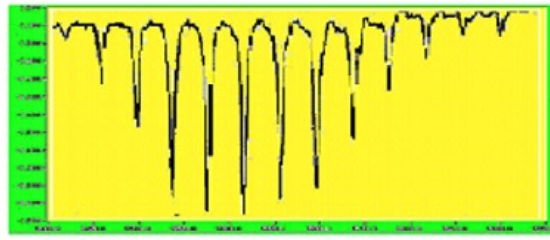


Figure 5. The 12-micron silica spectrum

The polystyrene microspheres show spectral lines that are randomly distributed. They are off the spectral band of the fluorescence spectrum of the pure rhodamine 6g dye solution in acetone. More time is needed to examine the cause of their behavior. Figures 6 and 7 show a typical spectral data of polystyrene spheres for 5- and 10-micron spheres, respectively. The lines are not equally spaced and irregular in their intensity.

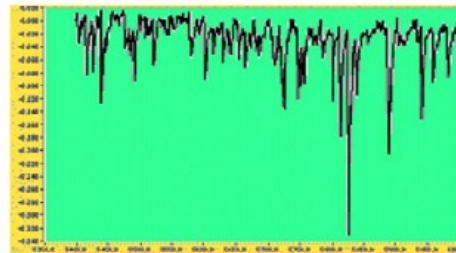
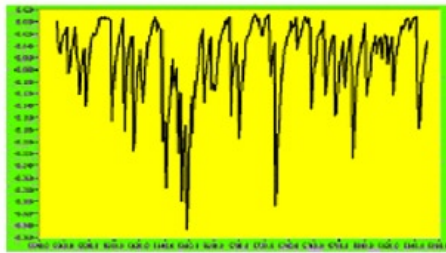


Figure 6. The 5-micron polystyrene spectrum **Figure 7.** The 10-micron polystyrene spectrum

Planned Future Work:

The building of the final prototype for this laser system is based on developing two different prototypes. Prototype I uses side pumping to pump the microspheres in the fiber, In Prototype II, the hollow fiber consists of two claddings. One cladding is used to guide the pumping laser and the other cladding is used to guide the emitted laser from the microspheres. A final design will be adopted based on knowledge gained from both prototypes.

Prototype I:

In this prototype, the microspheres doped with the proper lasing materials are injected into a single cladding hollow fiber. The pumping in this case is not guided along the fiber as in fiber laser amplifiers, but it will be side pumped through the transparent cladding. The fiber is then wrapped in multiple layers on a set of hollow Pyrex glass cylinders. The number of cylinders depends on the fiber length. The pumping xenon lamps are mounted inside each of the cylinders, as shown in Figure 8. One end of the fiber will be sealed and coated with a highly reflective coating so that the lasing energy from the fiber comes out from only one end. We will measure the laser energy for different sphere sizes with different lasing materials and correlate the lasing emission with the fiber length.

This study recommends the optimum size of the microsphere for each doping material and the fiber length needed to produce predetermined laser energy.

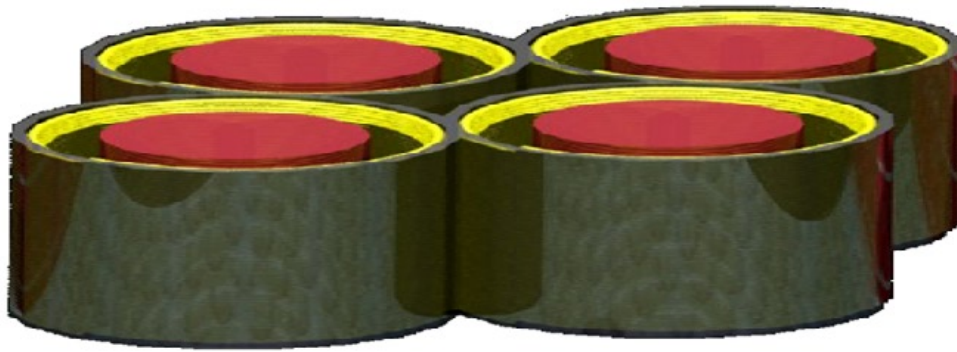


Figure 8. Schematic of the side pumping of the microspheres in the hollow fiber. The fiber is wrapped around the cylinder (yellow) and the pumping system (red).

Prototype II:

After identifying the proper size of the microspheres for each doping material in Phase I, the proper size microspheres are injected into a hollow double cladding fiber. The inner cladding is used for pumping the spheres and the second cladding for collecting the lasing emission from the microspheres (Figure 9). In this design, we are making use of the fiber laser amplifiers technology. Measurements of the power verses fiber length will be recorded and compared with the data of prototype I.

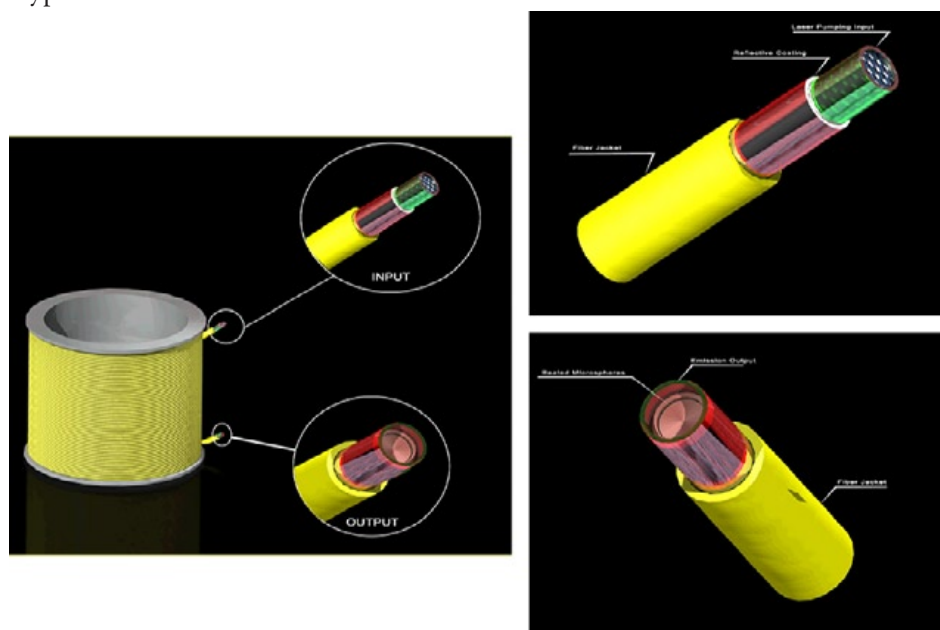


Figure 9. Schematic of the pumping along the first cladding (green) and the lasing emission along the second cladding (red). The yellow color is the fiber jacket.

The final design of the system will be built based on knowledge gained from prototype I and prototype II. Multi-size microspheres, with different doping lasing materials, will be injected into the hollow fiber to produce a system of broad tunability and reasonable level of lasing energy at each wavelength. The completion of the final design will bring the technology readiness-level 6.

Key Points Summary:

The microspherical laser is insensitive to temperature and pressure variations, which make it immune to the harsh space environments. It has very limited optical components, which makes it more rugged and less susceptible to the intense vibrations of the Space Shuttle during lift off. The pumping energy for the microspheres is orders of magnitude less than current space-laser systems. The system offers much broader tunability, which is unmatched by any available laser technology. In addition, the system is flexible, compact, lightweight, and inexpensive to build. Moreover, this system is in line with NASA's strategic objectives to develop novel laser systems with nontraditional laser media and unconventional techniques. The main criterion for success is obtaining the proper funding and the only risk factor for not achieving our objective is the lack of funding.